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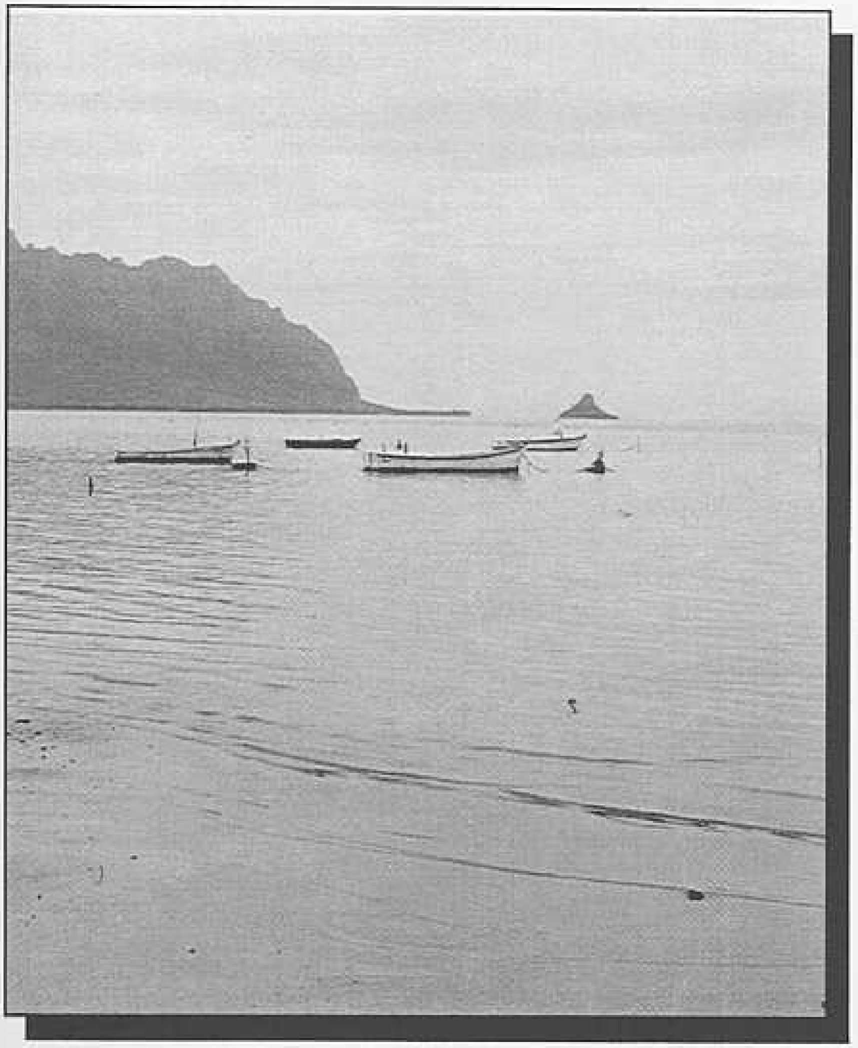

Department of Land and
Natural Resources

**Division of**
**Aquatic Resources**

Technical Report
94-01



# Fishery Data Collection System For Fishery Utilization Study of Kaneohe Bay Two-Year Interim Report

**May 1994**

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**John D. Waihee**
Governor

# FISHERY DATA COLLECTION SYSTEM FOR FISHERY UTILIZATION STUDY OF KANEOHE BAY TWO-YEAR INTERIM REPORT

A report on research conducted for the:
Main Hawaiian Islands Marine Resources Investigation (MHI-MRI)


**DIVISION OF AQUATIC RESOURCES**
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# Fishery Data Collection System for Fishery Utilization Study of Kaneohe Bay: Two-Year Interim Report

Alan Everson[1]


## ABSTRACT

A survey designed to estimate total fisheries catch and effort in Kaneohe Bay, Oahu, was funded by the Hawaii Department of Land and Natural Resources as a pilot study of the Main Hawaiian Islands Marine Resources Investigation (MHI-MRI) and is expected to continue through May 1993. A combination of two standard creel survey techniques was used to estimate seasonal and annual catch and effort for Kaneohe Bay. Effort and catch data were collected bi-weekly (weekend and weekday) on alternate weeks, using the roving creel (for effort) and access (for catch) techniques. Data were collected from December 1990 through May 1992. A secondary goal of the study was to chronicle user perceptions of resource abundance.

Preliminary expanded catch and effort estimates were calculated for all major fishing methods observed in Kaneohe Bay. Total annual landings for the period from March 1991 through February 1992 were estimated at 115,065 lbs, of which 48.79% (56,135 lbs) was taken by "passive fishing gears" (i.e. set nets and traps) and 51.21% (58,930 lbs) by "active gears" (all other methods). These gear definitions were based on the difficulty of detecting hourly fishing activity for the "passive" methods (in which fishing gear is left unattended for extended periods of time), making it necessary to calculate catch and effort as a daily (per trip) average, rather than on an hourly basis. Forty-five percent of landings by active methods consisted of tako, or day octopus (*Octopus cyanea*). Spear fishers were estimated to have the highest seasonal and annual catch of all active fishing methods. Tako comprised 88% percent of the 29,000 lbs speared annually in Kaneohe Bay (up to 92% seasonally). Estimated gill net catch exceeded 40,000 lbs in 1991 (35% of the total). In addition, 100,000 organisms (primarily featherduster worms, *Sabellastarte sanctijosephi*) were harvested by aquarium collectors during 1991. Annual effort was estimated at 1432 trips for passive fishing methods (gill nets, surround nets and traps) and 64,873 gear-hours for active methods. Pole-and-line fishing accounted for the majority of active seasonal and annual effort. More than 35,000 pole-and-line angler hours were estimated during 1991. Spear fishers had the highest active catch per unit effort (CPUE), while pole-and-line CPUE's were among the lowest. For active methods, the variance (as measured by relative standard error) was generally lower for effort estimates than for estimated catch. Expanded catch estimates for passive methods tended to be more variable (highest reported standard error) than either catch or effort for active methods.

The sampling program made possible a comparison of changes in seasonal and annual catch and effort for most of the fishing methods observed in Kaneohe Bay. Accurate total catch data for nearshore fisheries in Hawaii is lacking. Data gathered through this type of survey represent the first step toward obtaining information needed to formulate effective management plans for inshore fisheries.


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# Fishery Data Collection System for Fishery Utilization Study of Kaneohe Bay: Two-Year Interim Report

Alan Everson

## INTRODUCTION

The Main Hawaiian Island Marine Resources Investigation (MHI-MRI) was initiated in 1990 to evaluate the status of nearshore living marine resources in the main Hawaiian Islands (MHI). A steady decline in abundance of many of these resources over the last century has been reported by fishermen and researchers (Shomura 1987). MHI-MRI was devised as a cooperative effort, with participants from a diverse group of State, Federal, and private marine and fishery research organizations, to assess the cause and extent of this decline and recommend appropriate management methods to improve resource abundance.

A portion of the project is designed to evaluate the current status of fishery resources within the MHI. An important aspect of this evaluation involves designing a practical method for estimating the total catch and fishing effort affecting these resources. The sampling program must be formulated to obtain reliable estimates of total effort, catch per unit effort (CPUE), and harvest by method and species (or species group) within a given region. Important considerations include documenting total participation, type and number of gears used, and number or weight caught by species and area fished.

Few historical data exist regarding recreational nearshore catch and effort in Hawaii, and commercial catch reports are often incomplete or inaccurate. On-site fishing surveys (also known as creel surveys) have been used to a limited extent in Hawaii in an attempt to quantify island-wide commercial and recreational harvest (DLNR 1957-1966; Omnitrack 1991; Hamm and Lum 1992; Kahiapo and Smith in press). Unfortunately, most of these studies took place during a brief time period and were discontinued due to lack of funds, or in some cases a lack of focus and direction.

Programs to monitor commercial and recreational catch and effort have been successfully implemented in locations throughout the continental United States and Guam (Robson 1960; Malvestuto et al. 1978; Malvestuto 1983; Amesbury et al. 1991; Malvestuto and Knight 1991). Although there has been some variation in the sampling design and types of data collected in each survey, they have all had a common goal: to obtain as unbiased an estimate as possible of fisheries catch and effort, with minimal variance, using standard survey sampling techniques and limited project funds. These standard survey techniques will be discussed in greater detail below.

The present MHI-MRI research job, entitled "Fishery Utilization Study of Kaneohe Bay" (FUSKB), was designed as a pilot to evaluate fisheries catch and effort within Kaneohe Bay, Oahu. Other important aspects of this study were to identify the major fishery components, fishing gears and methods, and species targeted, as well as to determine the disposition of this catch and proportions of recreational/subsistence versus commercial fishers operating in the Bay. The latter information is needed to evaluate the proportion of the catch presently registered through the state's commercial fish catch reports, since only commercial fishers (those who sell a portion of their catch) are legally required to report (Hawaii Revised Statutes §189-3).

Since June 1990, the FUSKB study began gradually scoping important logistic constraints on censusing fish catches in Kaneohe Bay. Full-scale field sampling began later that year, following the determination and implementation of effective survey methods. The project continued through June 1993. This report details the results of surveys conducted during the first two years of the survey, using data collected from December 1990 through May 1992. A secondary goal of FUSKB was to chronicle user perceptions of the fishery and resource abundance, including past and present conditions and conflicts stemming from mixed uses (i.e. fishing, recreational boating, tour boat operations, and other activities). Preliminary results of this aspect of the study are included herein.

### STUDY AREA

The study site encompassed the area within Kaneohe Bay, on windward Oahu, extending from Pyramid Rock on the Mokapu Peninsula to Kualoa Point in the north (Figure 1). This area runs from the shore to the barrier reef and includes the leeward shore of Kapapa Island. Fishing activity on the Kapapa side of the barrier reef was also included. Kaneohe Bay is the largest sheltered body of water in the Hawaiian Islands (Smith et al. 1973), occupying approximately 12.8 by 4.3 km of the windward coastal zone.

## MATERIALS AND METHODS

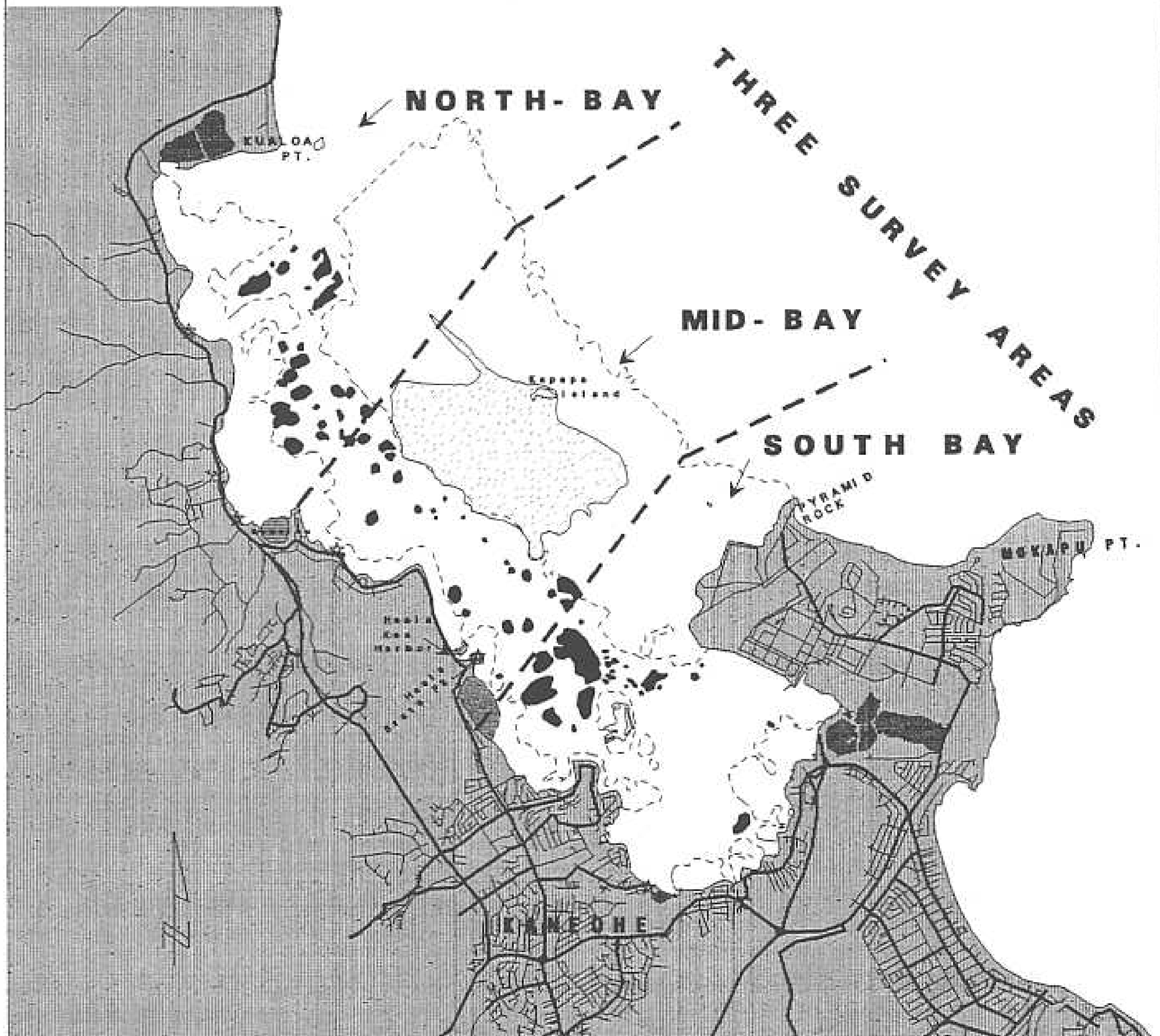
### GENERAL INFORMATION

Initially, data collection was patterned after the Hawaii Small Boat Fisheries Survey (HSBFS) commissioned by the State of Hawaii, Department of Land and Natural Resources (DLNR) in March 1990 and conducted at various ports around Oahu by a private contractor (Omnitrak 1991; Hamm and Lum 1992). One port of landing surveyed during HSBFS was Heeia Kea Harbor, in Kaneohe Bay. The FUSKB survey was designed to utilize the data base structure created for the HSBFS, building on methodology designed for that island-wide port-of-landing creel survey in an attempt to derive a more precise estimate of landings made strictly from within Kaneohe Bay. Methodology for the HSBFS was expanded to obtain more in-depth information on fishing activity within the Bay itself and a data entry program written for HSBFS (Hamm and Lum 1992) was modified to allow information on shoreline fishing, as well as landings at Heeia Kea Harbor, to be recorded.

The HSBFS collected two specific types of information: 1) the total number of vessels departing and returning to port was recorded by fishing method used, and 2) interviews were conducted to ascertain CPUE and total catch by method and species. FUSKB added an additional question to the HSBFS interview survey forms, to determine whether fishing activity actually took place inside or outside Kaneohe Bay. Although some HSBFS data were included, it soon became apparent that several modifications would be necessary to supplement data collection and gain a more complete picture of total catch and effort within the Bay.

Information obtained during the pre-survey stage of the study made it clear that a dual approach should be used to collect catch and effort data. Although only one major access point (Heeia Kea Harbor) is found within Kaneohe Bay, there are many private docks and piers along the sample route that aren't visible from Heeia Kea Pier. FUSKB was designed to utilize a variation on two techniques used successfully in other fisheries, roving and access-point creel survey methods.

# FIGURE 1: MAP OF KANEOHE BAY




**LEGEND**

- Patch reefs (some dredged)
- Fishponds
- Sandbar area
- ☆ Vantage points for observation and roving creel survey
- Major roads
- Minor roads
- Lines delimiting the three survey areas
- Fringing and barrier reefs

SOURCE: State of Hawaii - Geographic Information System (GIS)
DLNR, Division of Aquatic Resources, MHI-MRI GIS (1994)

During a roving creel survey, data are gathered by actively moving through the sample area along a predetermined route. The roving technique was used in the present study primarily as a means of documenting fishing effort (participation), regardless of access point used by fishers. Roving methods were supplemented by observation point techniques, using a high-power spotting scope, in order to achieve full coverage of the study area. In access point surveys, the creel clerk is stationed at a fixed location throughout the sample day and contacts the fisher at the end of a fishing trip. Since Heeia Kea Harbor is the primary point of access to Kaneohe Bay for most fishers, the majority of catch information for the FUSKB was gathered there via access point survey methods (see Malvestuto 1983 and Hayne 1991 for detailed accounts of both techniques).

The sample day was divided into a daylight period (dawn to dusk) and a nighttime period (dusk to dawn). Emphasis was placed on obtaining landings estimates for the daylight period. Sampling at night presents some unique problems, requiring slightly different methodology, so that nighttime fishing could only be addressed during the final year of the investigation (June 1992 - May 1993). Sampling was further stratified by day type, based on the observation that participation levels varied on weekdays as opposed to on weekends or holidays. The following is a detailed description of the two data collection techniques: 1) vantage point/roving creel surveys to collect participation data (total effort by method), and 2) access point surveys to collect CPUE and catch data.

PARTICIPATION DATA (ROVING SURVEY)

Data on participation rates (fishing effort as hourly number of gears and fishers by method) were gathered at various vantage points, located in shoreline areas throughout the Bay (see Figure 1). In order to discern the spatial distribution of fishing effort, the Bay was divided into three sectors (North, Mid and South Bay, also shown in Figure 1), approximately equal in total fishable area and comparable to designations used during previous Kaneohe Bay biological investigations (Smith et al. 1973; Smith et al. 1981). Further designations were used to indicate whether fishing effort was vessel-based or shore-based, and if this activity took place inshore, in mid-bay waters, or offshore. A high powered (20-60x zoom) spotting scope was used to document total fishing activity occurring every hour.

Estimated participation rates (fisher-hours or effort-days by method) were calculated during sample days on which the spotting scope was used to obtain counts of fishers from the primary vantage point at Heeia Kea State Park (Figure 1). It was possible to view most of the Bay and observe the method used by each fisher from this vantage point. In this manner an instantaneous estimate of participation rates by method was made. Roving counts conducted simultaneously via automobile were used to enumerate shoreline activity out of view of the Heeia vantage point. The drive-by route originated from Heeia State Park and proceeded either to the north or south of the park (direction chosen randomly). A surveyor stopped at a designated area and ascertained (with the aid of binoculars and/or a spotting scope) the number of fishers and types of fishing activity taking place.

The sample day was divided into two shifts. The morning shift began at about 6:00 a.m., depending on light conditions, and ran until noon. The afternoon shift ran from noon to dusk. Sampling was conducted on a one-hour-on-one-hour-off basis. For example, if the hour between 6:00 and 7:00 was used to record participation rate data from the vantage point near Heeia Kea, the following hour would be used to verify the accuracy of these counts, using a combination of roving methods and persistent visual observation. Often it was not readily apparent what type of activity was taking place, especially when an empty boat was seen anchored on the reef. The second hour was used to determine whether a given party was engaged in a fishing operation or merely diving or boating for pleasure. Sample times and days were rotated, so all hours of the day could be covered equally.

Data for each time period were recorded on a participation survey form (Appendix 1) and included:

- Total number of vessels and fishers by sector.

- Type of activity (i.e. fishing, SCUBA, recreation, tour group) per boat or fisher.

- For fishing boats: method, number of gears and fishers.

- For non-fishing boats: a tally of the number (of boats) observed during the hour.

- Weather conditions (wind speed, sea height).

Fishing methods were arbitrarily defined as being either "passive" or "active", based on the difficulty of detecting hourly fishing activity for the passive gears, which are left unattended for extended periods of time. Passive methods (such as fishing with gill or surround nets or traps) were treated differently from active methods, for which catch and effort was more easily estimated on an hourly basis. Any passive fishing activity observed during a sample day was recorded on a passive-effort-day basis, whether the method was viewed during one or more hours. Each passive fishing party was counted only once during a sample day.

CPUE AND TOTAL CATCH BY METHOD (ACCESS POINT SURVEY)

Catch and CPUE data were collected during access point surveys. The access surveys were originally designed to take place at various landing sites within the Kaneohe Bay area. The surveyor recorded the number and type of vessels leaving the area and, if possible, the fishing method used. The same information was recorded when the vessel returned to port. A sample day began one hour before sunrise and ended an hour after sunset. This boat log information (Appendix 2) was used during the HSBFS study to estimate total effort for a given port day. Its main use in the present study was as a record of total boating activity, including departure and arrival times, to help verify information gathered during the interview process. Since multiple ramps are used at some sites, it also served as a record of usage levels by boat ramp.

Fishers were approached upon their return to port at the completion of a fishing day. Information recorded during an interview (Appendix 3) included area fished (inside or outside the Bay), total time spent fishing by method, and total catch (number and weight) by method and species. Any comments regarding the general state of the fishery were also recorded. Initially, FUSKB personnel attempted to obtain a random sample of fishers, regardless of whether they fished inside or outside the Bay. After examining the first two quarters of data, it was found that a large percentage of fishers intercepted at Heeia Kea Harbor (50-80%) fished outside the Bay. Thus, on many initial sample days very few inside-the-Bay interviews were obtained. Beginning in the summer of 1991, survey efforts were focused on obtaining interviews from those fishing inside the Bay and those fishing outside the Bay were interviewed only as time allowed.

The primary access point for Kaneohe Bay is at Heeia Kea Harbor, which is the most heavily used boat launching facility in the area. Other boat launch facilities within the survey region include Kaneohe Bay Yacht Club, Makani Kai Marina, and Kaneohe Marine Corps Air Station. To date these other facilities have been considered, but have not been adequately sampled due to limited access and lack of personnel. Several shoreline areas and mudflats have also been identified as popular mooring spots. These areas may be surveyed in the future, as time and personnel permit.

Since interviews were conducted upon trip completion, this sampling method eliminated the problem of analyzing CPUE and total catch data for incomplete trips. Another advantage is that many fishers can be interviewed at a single location. This saves time by eliminating the need for the surveyor to move from place to place and wait for the fisher to complete a trip and return to shore. The major disadvantage of this technique is that not all fishing methods used in Kaneohe Bay are represented by fishers who pass through Heeia Kea Harbor. These other methods include shorecasting, cast-netting, dip-netting, and inshore crab netting. Additional catch and effort data for these fishing methods were obtained during the roving portion of the participation survey. Fishers were approached whenever possible along the survey route and interviewed as above.

## SAMPLING FREQUENCY

Sampling effort was stratified by day type and took place during one weekday (WD) and one weekend or holiday (WE/H) per week. The sample days were chosen randomly in advance and were conducted using a rigid schedule to reduce sampling bias. Participation (effort) and access point (CPUE) data were collected on separate days during alternate weeks. Occasionally, enough personnel were available to conduct both surveys on the same day.

Data were coded and entered into a computer file using the dBASE IV+ data entry system adapted from the HSBFS survey (Hamm and Lum 1992). Daily participation logs were entered as separate files using the data entry programs written for this purpose. Daily boat log, interview log (number of fishers, total hours fished and total catch by method) and catch log (catch by species and method) were also entered as separate files.

## FISHER PERCEPTIONS

Several less-structured, informal interviews were conducted with Bay fishers throughout the term of the study to gain firsthand knowledge of past and present fishing practices in Kaneohe Bay. In addition, voluntary responses of this nature were recorded during access interviews. Results from these interviews and information gathered on the perceived state of the fishery, including fishers' views on the shared uses of Kaneohe Bay, will also be included in the discussion.

DATA ANALYSIS: EXPANSION METHODS

Estimates of total catch and effort were obtained using the basic data expansion technique described by Malvestuto et al. (1978). Data processing was accomplished using a SAS program (Statistical Analysis System software, SAS Institute 1988), written by S.P. Malvestuto (Fishery Information Management Systems, P.O. Box 3607 Auburn, AL 36831-3607) and modified in places by the author. The entire survey day was sampled equally, in order to determine the amount of fishing activity (participation) that occurred at various times throughout the day. This is in contrast to the non-uniform probability method employed by Malvestuto et al. (1978), in which the fishery surveyed is divided into time blocks and sampling probabilities are assigned proportional to the amount of fishing activity known from previous surveys to occur during any given period. Within-day stratification can be used later to survey the fishery at Kaneohe, once the entire day is properly enumerated. A total of at least 24 days (12 WD and 12 WE/H) were sampled each quarter. Data expansions were calculated by quarters of the year to evaluate seasonal differences in estimates of total catch, effort and CPUE.

Estimated participation rates were calculated in fisher-hours for active methods and in effort-days (trips) for passive methods. Fisher-hours rather than gear-hours were used for active methods, although both measures of participation were examined, since it was apparent that most fishers in Kaneohe Bay use only one gear (or one at a time); thus, fisher-hours for active methods are equivalent to gear-hours. For most passive methods (gill and surround nets), an "effort-day" could also be defined as a "boat-day", "gear-day" or "fishing trip", since a single net is used by each fishing party. However, the nets vary in length, depth and mesh size, so that fishing power is not necessarily equivalent. For trap fishing the definition of a unit of effort is even more difficult, since one or more traps are carried on some vessels, but not all of these are necessarily fished at once or all day. Given the small number of trap interviews, it was impossible to develop an accurate estimate of catch per trap-day, so catch per effort-day (or per trip) had to be accepted as a first-order estimate.

Since sampling took place every other hour, participation-hours for active methods were multiplied by two to get total hours for the whole survey day (approximately 12-14 hours, depending on the season). Mean quarterly participation hours per survey day ($MPD_{ij}$) were calculated and summed for each active method, as:

$$MPD_{ij} = \sum^{n} \sum^{x} (2p_{xij})/n_i$$

where,

$p_{xij}$ = the number of fishers seen using the jth method in each of x hourly counts within a survey day of the ith stratum (WD or WE/H and quarter),

x = the number of one-hour counts made per survey day (one count completed every other hour),

n = the number of days in the quarter, and

$n_i$ = the number of days sampled in the ith stratum.

For passive methods, total effort-days were summed for each method and averaged over the entire quarter (for WD and WE/H separately). Days with zero participation-hours (or days) were factored into the quarterly mean for both passive and active methods. The standard error of mean daily participation per quarter ($SEMPD_{ij}$) was calculated, using the standard formula:

$$SEMPD_{ij} = \sqrt{\left(\frac{\{\Sigma(p_{ij})^2 - [(\Sigma p_{ij})^2/n_i]\}}{(n_i-1)}\right)\left(\frac{1}{n_i}\right)}$$

with (daily) variance:

$$VMPD_{ij} = (SEMPD_{ij})^2$$

Since the number of days sampled in a quarter exceeded 10% of the total number of days in a quarter, the finite population correction factor could be used to adjust (reduce) total variance (Cochran 1977), giving the variance of quarterly mean participation for each method ($VMPQ_{ij}$) as:

$$VMPQ_{ij} = (1 - n_i/N)\,(N)^2\,(VMPD)$$

$$= (1 - n_i/N)\,(N)^2\,(SEMPD_{ij})^2$$

where N = the total number of WD or WE/H in the quarter and all other variables have been defined. Relative standard error (RSE) was calculated for participation (and other estimates to be described), by dividing the standard error by the estimate and multiplying by 100. This provides a relative measure of variance, which is independent of the units employed, so variance can be compared between estimates with different units (i.e. effort, catch, cpue) (Malvestuto et al. 1978, Dent and Wagner 1991).

Most catch information was obtained on alternate weeks during interviews conducted at Heeia Kea Harbor. Additional catch data were gathered on roving survey days. Estimates of CPUE (lbs or number of organisms per fisher-hour for active methods, or per effort-day for passive methods) were calculated by dividing the sum of total catch by the sum of total effort for each method, over all sample days within a quarter, for a total ratio estimate of CPUE (Cochran 1977, Malvestuto 1983), as:

$$CPUE_{ij} = \frac{C_{ij}}{E_{ij}}$$

where,

$C_{ij} = \sum^{n_i} c_{ij}$ = total catch (lbs or number of organisms) recorded for all interviews for the jth method over all survey-days in the ith quarter;

$E_{ij} = \sum^{n_i} e_{ij}$ = total effort (fisher-hours for active or effort-days for passive methods) recorded for all interviews for the jth method over all survey days in the ith quarter; and

$n_i$ remains as defined above.

This is in contrast to a means-of-ratio estimate, where daily CPUE estimates are averaged over the number of days sampled (Malvestuto 1983). Variance of the CPUE estimate can be determined from the standard variance-of-a-ratio estimator (Cochran 1977), as:

$$VCPUE_{ij} = \frac{\dfrac{\{\Sigma(c_i)^2 - 2(CPUE_i)(\Sigma c_i e_i) + (CPUE)^2\,\Sigma(e_i^2)}{(n_i-1)}}{n_i\left[\dfrac{\Sigma e_i}{n_i}\right]^2}$$

with standard error $SECPUE_{ij} = \sqrt{VCPUE_{ij}}$

and relative standard error $RSE_{CPUEij} = (SECPUE_{ij}/CPUE_{ij})(100)$.

Average CPUE over all WD and WE/H in the quarter was estimated as the weighted sum of the products of each method's CPUE and an appropriate weighting factor ($w_i$), representing the proportion of each day type (WD or WE/H) in the stratum.

$$QCPUE_{ij} = \sum^{i}(w_i)(CPUE_{ij})$$

where $w_i = n_i/N$

and $n_i$ = the number of WD or WE/H in the quarter (which may vary slightly from one quarter to another).

Quarterly variance of CPUE for each method was estimated in the same manner, from the weighted sum of variance for WD and WE/H (except $w_i$ is squared in the variance formula). Standard errors were based on the square root of the variance, and RSEs were computed as described previously. Quarterly expanded catch (QEC) estimates were made by summing quarterly method-specific expanded catch, based on the product of total quarterly participation ($QPD_j$), and quarterly CPUE ($QCPUE_{ij}$), as follows:

$$QEC = \sum_{ij} QP_{ij}(QCPUE_{ij})$$

where,

$QP_{ij}$ = total quarterly participation rate for each gear (hours or days)

$= (MPD_{ij(WD)})(n_{WD}) + (MPD_{ij(WE/H)})(n_{WE/H})$

The variance of expanded catch was calculated for each quarter and method, using the formula for the variance of a product (Meyers 1975). Standard error and RSE for these estimates were computed as described above. Once sufficient data were obtained, expanded quarterly totals were summed to obtain annual estimates of harvest (total catch), participation rates, CPUE (and their respective variances).

Finally, species composition of the total catch was estimated for the active methods by multiplying the average percent species composition (by weight) for each method from interview data by the expanded catch estimate by method. Variance for individual species catch is not reported, but is undoubtedly high due to the variable number of methods used and species caught.

## RESULTS

Results to date have been enumerated for six quarters, winter 1990 (December 1990, January, February 1991) through spring 1992 (March, April, May 1992). Annual estimates of catch and effort were calculated for the year March 1991 to February 1992. Data for winter 1990 and spring 1992 are also included for comparison.

Results obtained from the participation survey (expanded effort) make it possible to quantify and rank the various fisheries (or fishing methods) used within Kaneohe Bay (Figure 2; Table 1). Most of these activities can take place from shore (shore-based) or from a vessel fishing in the Bay (vessel-based). They are listed below roughly in order from most to least quarterly effort hours, except those gears/methods classed as "passive" (effort measured in days fished), which are marked by an asterisk (*).

**Pole-and-line fishing** -- includes spin casting (whipping), bottom fishing, shore casting, dunking, and handlining

**Spear fishing** -- includes spearing while skin or SCUBA diving, and spearing from a boat without entering the water

**Trolling** -- various sized vessels are used; this method is sometimes hard to distinguish from pole-and-line fishing when collecting boat log data, unless fishing lines are being set up or are already in the water

**Crab Netting** -- hoop style crab lift nets are used

**Cast Netting** -- a circular throw net is cast and retrieved actively in relatively shallow water

**Invertebrate Collecting (for Aquarium)** -- using in-water, dive collecting methods; this fishery includes commercial aquarium collectors who target featherduster worms, anemones, small crabs, and (occasionally) fishes

**Limu (seaweed) Harvesting** -- limu is harvested by hand from various shallow reef areas

**Dip Netting** -- often used to catch small fishes and crustaceans to be used as bait

**Fence Netting** -- short length of net attached between two poles, used to catch shrimp and small fishes

**Aquarium Netting** -- using dip nets to catch fish for the commercial aquarium trade

**Trapping (*)** -- includes fish, lobster, and crab traps

**Gill Netting (*)** -- a long (up to over 1000 ft.) rectangular set net that gills the fish, usually placed at right angles to the current or along the edges of reefs in such a way as to intercept schools moving along the bottom or surface.

**Surround Netting (*)** -- a long rectangular net, set in such a way as to encircle a school of fish (set actively, but the catch is often retrieved over a period of hours or days).

**TABLE 1. Quarterly Estimates of Mean Daily Effort-Hours and Standard Error (SE) by Weekday and Weekend/Holiday (WE/Hol) for Various Methods Observed in Kaneohe Bay During 1991**

| FISHING METHOD (OR GEAR) | SPRING 1991 | | | | SUMMER 1991 | | | | FALL 1991 | | | | WINTER 1991 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | |
| | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| TROLL | 10.0 | 4.2 | 44.3 | 12.1 | 13.7 | 3.2 | 34.7 | 7.7 | 7.3 | 2.8 | 18.6 | 5.0 | 1.0 | 0.7 | 6.4 | 2.5 |
| SPEAR | 21.3 | 9.9 | 41.1 | 7.9 | 24.7 | 8.7 | 68.3 | 20.6 | 53.3 | 9.6 | 109.1 | 19.5 | 29.0 | 10.4 | 50.4 | 7.7 |
| POLE & LINE | 58.7 | 10.9 | 146.6 | 31.1 | 101.0 | 20.3 | 240.7 | 38.8 | 55.7 | 9.9 | 206.6 | 37.5 | 23.5 | 8.2 | 109.8 | 14.6 |
| INVERTEBRATE COLLECTORS | 3.0 | 1.1 | 0.6 | 0.6 | 7.0 | 1.8 | -- | -- | 14.7 | 2.8 | 2.3 | 2.0 | 7.0 | 2.4 | 1.3 | 0.7 |
| CRAB NET | 8.7 | 1.6 | 9.4 | 2.2 | 10.3 | 4.0 | 10.3 | 3.7 | 6.3 | 2.3 | 6.3 | 1.6 | 6.5 | 1.6 | 6.7 | 1.6 |
| CAST NET | 7.0 | 2.3 | 2.9 | 0.4 | 3.3 | 0.7 | 3.0 | 1.7 | 5.0 | 3.1 | 4.0 | 1.1 | 1.0 | 0.8 | 2.4 | 1.1 |
| AQUARIUM NET | -- | -- | 0.6 | 0.6 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2 | 0.2 |
| DIP NET | 4.0 | -- | 5.0 | 1.0 | -- | -- | -- | -- | -- | -- | 4.0 | -- | 2.7 | 0.7 | 6.0 | -- |
| FENCE NET | -- | -- | 4.0 | -- | 2.7 | 0.7 | 7.0 | 1.0 | -- | -- | -- | -- | -- | -- | -- | -- |
| LIMU (HANDPICKED) | 2.7 | 1.6 | 5.7 | 0.7 | 2.0 | 0.9 | 3.3 | 1.2 | -- | -- | 2.0 | 1.7 | 0.3 | 0.1 | 0.4 | 0.4 |
| GILL NET* | 3.3 | 0.8 | 2.4 | 0.8 | 2.5 | 0.8 | 4.7 | 1.2 | 4.2 | 0.8 | 6.1 | 1.0 | 1.2 | 0.4 | 2.3 | 0.7 |
| SURROUND NET* | -- | -- | 0.1 | 0.1 | 0.2 | 0.1 | -- | -- | -- | -- | -- | -- | -- | -- | 0.6 | 0.2 |
| TRAPS* | 0.8 | 0.5 | 0.6 | 0.3 | 0.8 | 0.3 | 0.5 | 0.3 | 1.2 | 0.4 | 0.3 | 0.2 | 0.3 | 0.2 | 0.3 | 0.2 |

TABLE LEGEND

Mean = Mean daily effort, measured in fisher-hours for most methods
Mean = Mean daily effort, measured in effort-days for methods marked by an asterisk (*)
SE = Standard error

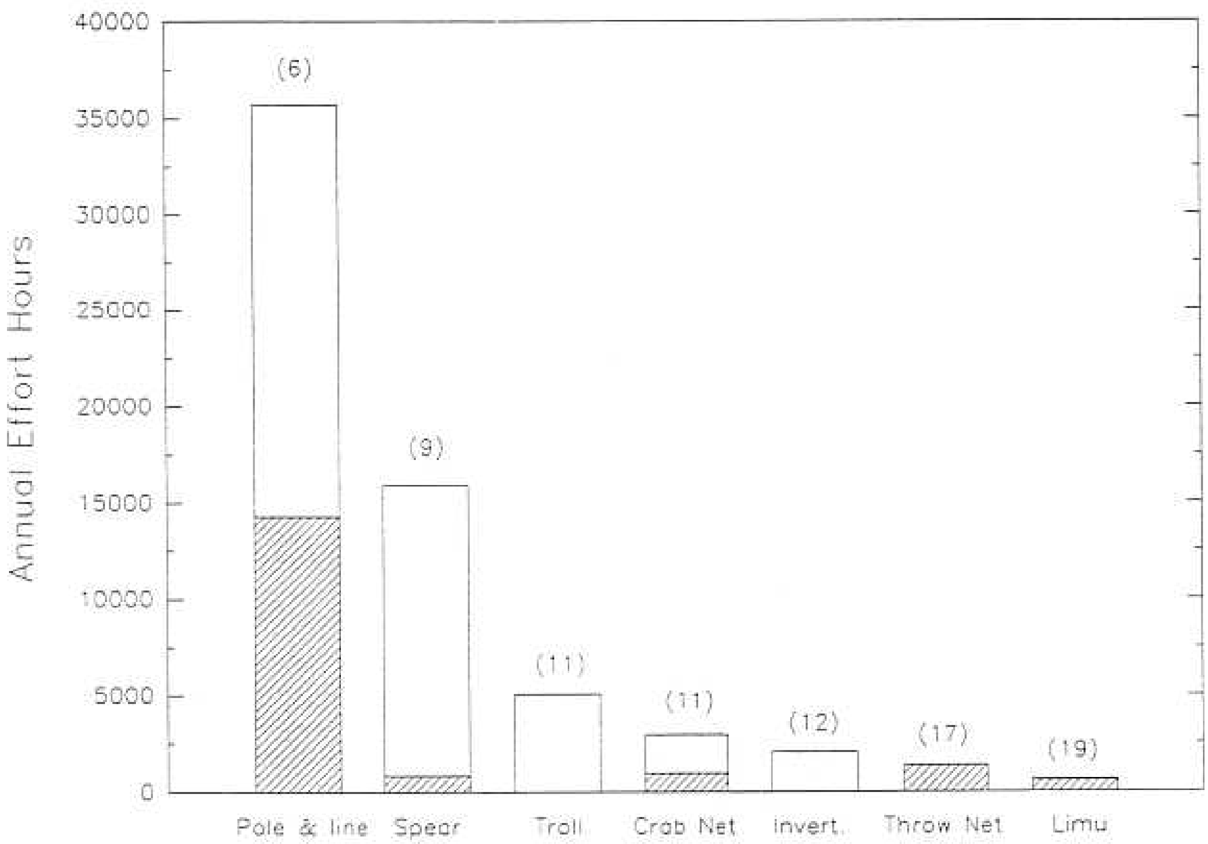



FIGURE 2: Estimated Annual (1991) Active Fishing Effort in Kaneohe Bay

NOTES:
Numbers in parentheses indicate relative standard error (RSE)
Shaded (slashed) portion of bar indicates shore-based activity

Pole-and-line fishing, spearing, trolling, crabbing, cast netting, invertebrate collecting, and limu harvesting are considered active fishing methods. Since these activities are visible as they occur, effort can be calculated in hours fished. Gill and surround netting, and trapping are deemed passive methods; that is, due to extended soak times it is often difficult to visually discern total hours fished.

Pole-and-line fishing accounted for most active fishing effort within the Bay during all quarters surveyed in 1991. (Figure 3; Tables 1,2). From 2.8 (summer) to 5.6 times (winter) more mean daily effort hours went into this activity on WE/H versus WD over all quarters. Seasonally, pole-and-line fishing effort was greatest during summer (13,482 hours) and lowest during winter (4,727 hours; Table 3). Variance of these estimates, as expressed by RSE, remained between 12 to 13% throughout all quarters sampled in 1991 and dropped to 10% during spring 1992. More than 35,000 annual pole-and-line angler-hours were estimated to have been expended during 1991, with nearly 40% (14,283 hours) of this activity occurring from shore (Figure 2). This accounted for 51.4% of the annual active fishing effort.

Spear fishing was the next most frequently encountered fishing method in Kaneohe Bay during 1991 (Figure 4; Tables 1,2). Mean daily effort was highest on WE/H, rather than on WD; estimated at about 1.72 times as much during the winter to 2.72 times as much during summer. Effort peaked (6,528 hours) and RSE's were lowest (12%) during fall while effort was lowest (2,537 hours) and RSE's were highest (25%) during spring 1991 (Table 3). Effort during spring 1992 more than doubled (5,221 hours) over spring of the previous year. Annual (1991) spear fishing effort peaked at 15,926 hours (22.9% of total active effort) and 95% of this took place from boats offshore (Figure 2). Only 2.9% of the spear fishers used SCUBA, while 21% used the traditional method of spearing from the boat without entering the water.

Trolling was the third most popular method in terms of fishing effort (Figure 5; Tables 1,2). Mean daily effort (angler-hours) was 2.5 times greater during summer and up to 6.0 times greater during winter for WE/H versus WD activity. The total amount of effort was highest (1,887 angler-hours) during summer and lowest (254 hours) during winter (Table 3). The opposite trend was seen for RSE's, which (as with spear fishing) were lower during periods of peak fishing effort. Trolling effort dropped substantially during the spring of 1992 (818 hours; as compared to 1,914 hours during the spring of 1991). Estimated annual trolling effort exceeded 5,000 hours (7.3% of total active effort) during 1991 (Figure 2).

Several other active methods of less importance were recorded during the participation counts (Tables 1-3). Annual effort for these ranged from 646 hours for limu collecting to 2941 hours for crab netting (Figure 2). Crab netting activity peaked during summer (951 hours); limu picking (334 hours) and cast netting (524 hours) peaked during the spring; and invertebrate collecting (Figure 6) was at its highest level (963 hours) during the fall. The mean daily fishing effort was generally higher on weekends and holidays, except for invertebrate collectors. Very few invertebrate collectors were seen on weekends or holidays.

Other fishing activities observed included dip and fence netting, and tropical fish (aquarium) collecting (Tables 1-3). Estimated effort over all active methods combined per quarter was also calculated. Again, effort peaked during summer (22,373 hours) and was lowest during both winter quarters (at 13,827 hours during 1990 and 10,421 hours in 1991; Figure 7). Total active effort for 1991 was estimated at 67,243 hours (4.0 RSE).

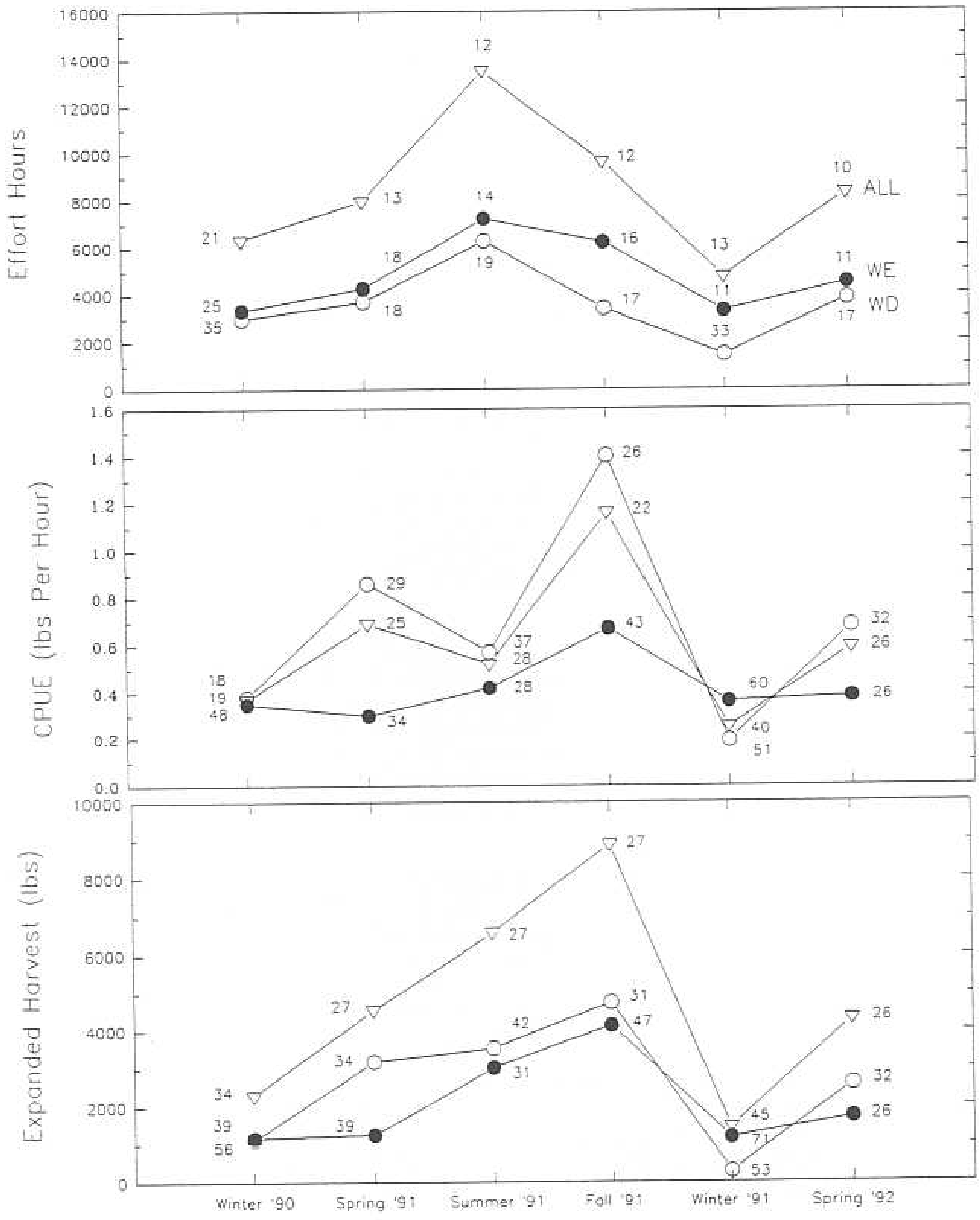



FIGURE 3: Quarterly Expanded Effort, CPUE and Expanded Harvest
POLE & LINE FISHING

**TABLE 2. Quarterly Estimates of Total Fishing Effort by Weekday versus Weekend/Holiday (WE/Hol) for Various Methods Observed in Kaneohe Bay During 1991**

| FISHING METHOD (OR GEAR) | SPRING 1991 | | | | SUMMER 1991 | | | | FALL 1991 | | | | WINTER 1991 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | | Weekdays | | WE/Hol | |
| | TE | RSE | TE | RSE | TE | RSE | TE | RSE | TE | RSE | TE | RSE | TE | RSE | TE | RSE |
| TROLL | 630.0 | 40.2 | 1284.3 | 23.9 | 847.3 | 22.0 | 1040.0 | 19.9 | 447.3 | 36.4 | 557.1 | 23.7 | 61.0 | 61.0 | 193.3 | 32.9 |
| SPEAR | 1344.0 | 44.1 | 1193.1 | 16.7 | 1529.3 | 33.3 | 2050.0 | 27.0 | 3253.3 | 17.0 | 3274.3 | 15.6 | 1769.0 | 33.5 | 1513.3 | 12.8 |
| POLE & LINE | 3696.0 | 17.6 | 4250.6 | 18.3 | 6262.0 | 19.1 | 7220.0 | 14.4 | 3395.7 | 17.0 | 6197.1 | 15.9 | 1433.5 | 32.7 | 3293.3 | 11.1 |
| INVERTEBRATE COLLECTORS | 189.0 | 35.7 | 16.6 | 87.1 | 434.0 | 25.0 | -- | -- | 894.7 | 18.2 | 68.6 | 75.6 | 427.0 | 31.8 | 40.0 | 41.8 |
| CRAB NET | 546.0 | 17.6 | 273.4 | 20.0 | 640.7 | 36.6 | 310.0 | 32.1 | 386.3 | 34.1 | 188.6 | 22.3 | 396.5 | 22.8 | 200.0 | 20.1 |
| CAST NET | 441.0 | 31.2 | 82.9 | -- | 206.7 | 19.0 | 90.0 | 50.5 | 305.0 | 58.6 | 120.0 | 23.4 | 61.0 | 70.5 | 73.3 | 37.5 |
| AQUARIUM NET | -- | -- | 16.6 | 87.1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.7 | 83.7 |
| DIP NET | 252.0 | -- | 145.0 | 19.3 | -- | -- | 210.0 | 13.8 | -- | -- | 120.0 | -- | 162.7 | 24.4 | 180.0 | -- |
| FENCE NET | -- | -- | 116.0 | -- | 165.3 | 24.4 | 15.0 | 61.1 | -- | -- | -- | -- | -- | -- | -- | -- |
| LIMU (HANDPICKED) | 168.0 | 57.3 | 165.7 | 10.4 | 124.0 | 42.5 | 100.0 | 33.0 | -- | -- | 60.0 | 74.0 | 15.3 | 93.2 | 13.3 | 83.7 |
| GILL NET* | 210.0 | 23.0 | 70.4 | 28.1 | 155.0 | 29.0 | 140.0 | 23.0 | 254.0 | 19.0 | 184.0 | 14.7 | 76.2 | 30.7 | 70.0 | 24.6 |
| SURROUND NET* | -- | -- | 4.1 | 87.1 | 10.3 | 95.0 | -- | -- | -- | -- | -- | -- | -- | -- | 16.7 | 26.4 |
| TRAPS* | 52.5 | 54.5 | 16.6 | 45.3 | 51.7 | 35.0 | 120.0 | -- | 71.2 | 32.7 | 8.6 | 56.5 | 15.3 | 61.0 | 10.0 | 59.2 |

TABLE LEGEND

TE = Total effort, measured in fisher-hours for most methods
TE = Total effort, measured in effort-days for methods marked by an asterisk (*)
RSE = Relative standard error
= (100 x SE/total)

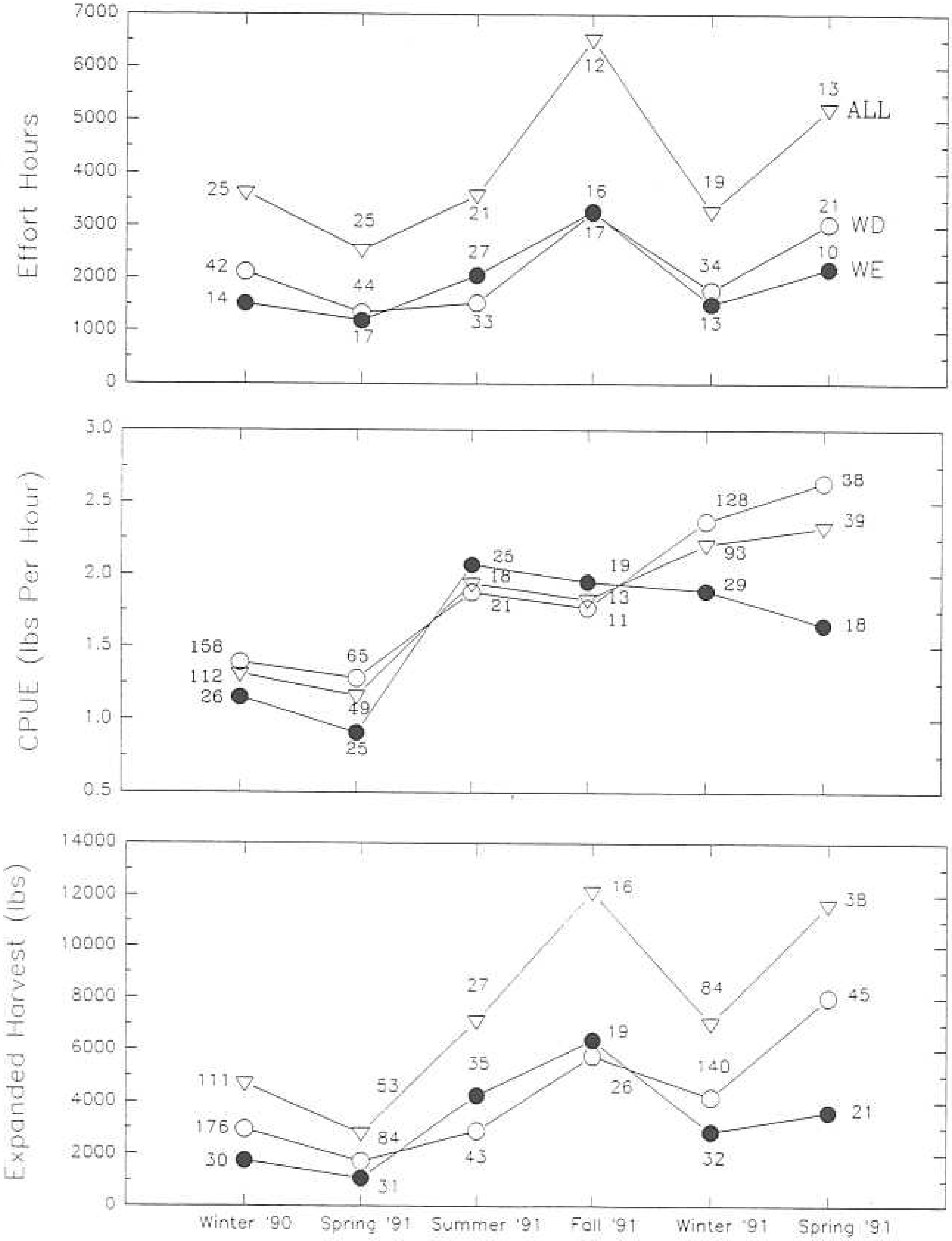



FIGURE 4: Quarterly Expanded Effort, CPUE and Expanded Harvest
SPEAR FISHING

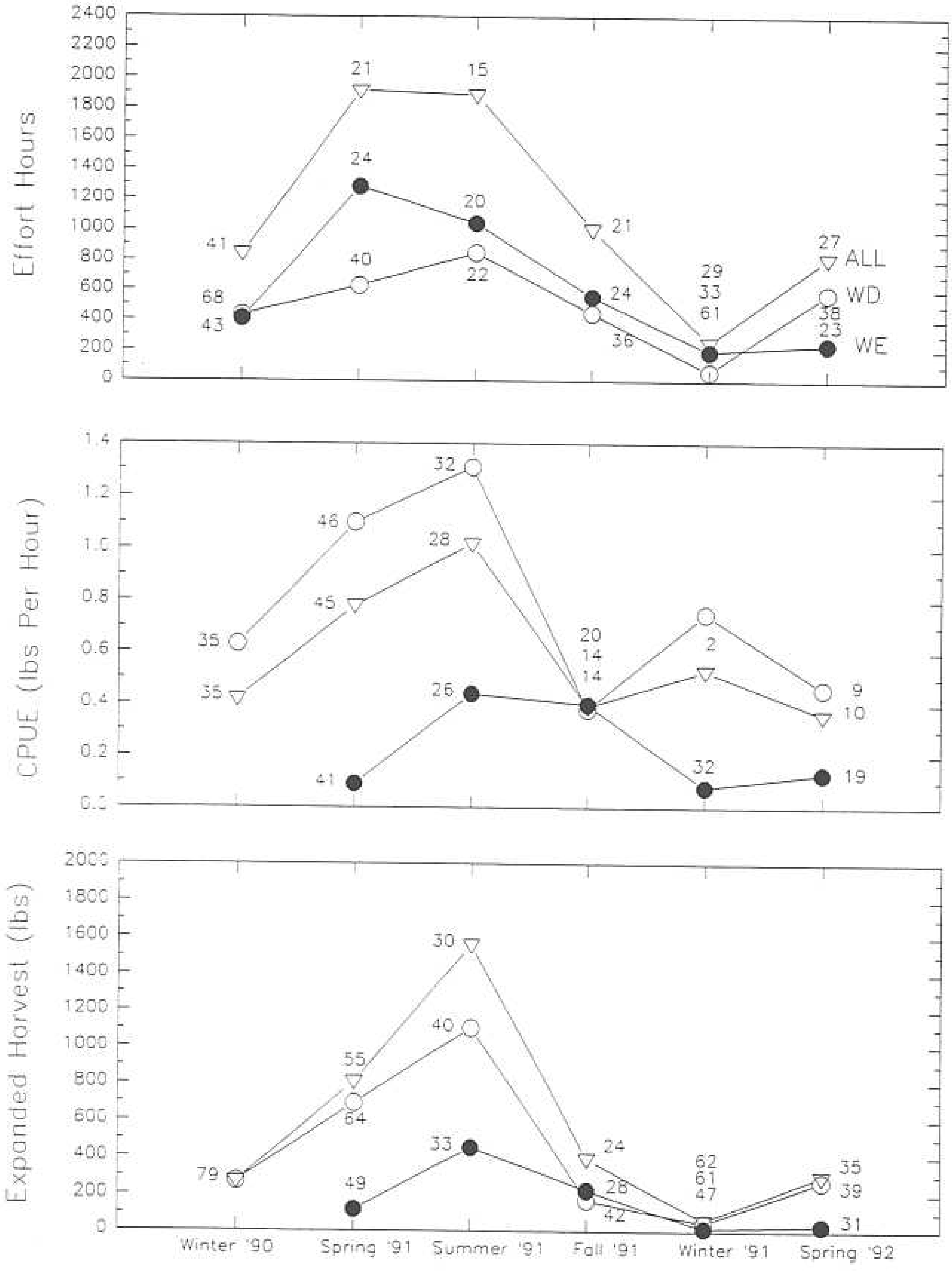



FIGURE 5: Quarterly Expanded Effort, CPUE and Expanded Harvest
TROLLING

**TABLE 3. Quarterly Estimates of Total Effort (Fisher-Hours) for Various Fishing Methods Observed in Kaneohe Bay During 1991**

| FISHING METHOD (OR GEAR) | SPRING 1991 | | SUMMER 1991 | | FALL 1991 | | WINTER 1991 | |
|---|---|---|---|---|---|---|---|---|
| | Total Effort (fisher-hrs.) | RSE* (%) | Total Effort (fisher-hrs.) | RSE* (%) | Total Effort (fisher-hrs.) | RSE* (%) | Total Effort (fisher-hrs.) | RSE* (%) |
| TROLL | 1914.3 | 20.8 | 1887.3 | 14.7 | 1004.5 | 20.9 | 254.3 | 29.0 |
| SPEAR | 2537.1 | 24.6 | 3579.3 | 21.0 | 6527.6 | 11.5 | 3282.3 | 19.0 |
| POLE & LINE | 7946.6 | 12.8 | 13482.0 | 11.8 | 9592.8 | 11.9 | 4729.8 | 12.6 |
| INVERTEBRATE COLLECTORS | 205.6 | 33.6 | 434.0 | 25.0 | 963.2 | 17.7 | 467.0 | 29.3 |
| CRAB NET | 819.4 | 13.5 | 950.7 | 26.8 | 574.9 | 24.1 | 596.5 | 16.6 |
| CAST NET | 523.9 | 26.3 | 20.2 | 296.7 | 425.0 | 42.6 | 134.3 | 38.0 |
| AQUARIUM NET | 16.6 | 87.1 | ---- | ---- | ----- | ---- | 6.7 | 83.7 |
| DIP NET | 397.0 | 7.0 | ---- | ---- | 120.0 | ---- | 342.7 | 11.6 |
| FENCE NET | 116.0 | --- | 375.3 | 13.2 | ----- | ---- | ---- | ---- |
| LIMU (HANDPICKED) | 333.7 | 29.3 | 224.0 | 27.8 | 60.0 | 74.0 | 28.6 | 63.2 |
| GILL NET* | 280.4 | 18.5 | 295.0 | 18.8 | 438.4 | 12.6 | 146.2 | 19.9 |
| SURROUND NET* | 4.1 | 87.1 | 10.3 | 95.0 | ---- | ---- | 16.7 | 26.5 |
| TRAPS* | 69.1 | 42.8 | 66.7 | 30.4 | 79.7 | 29.8 | 25.2 | 43.7 |

TABLE LEGEND

Total effort measured in effort-days for methods marked by asterisk (*)
RSE = Relative standard error = (100 x standard error/total estimate)

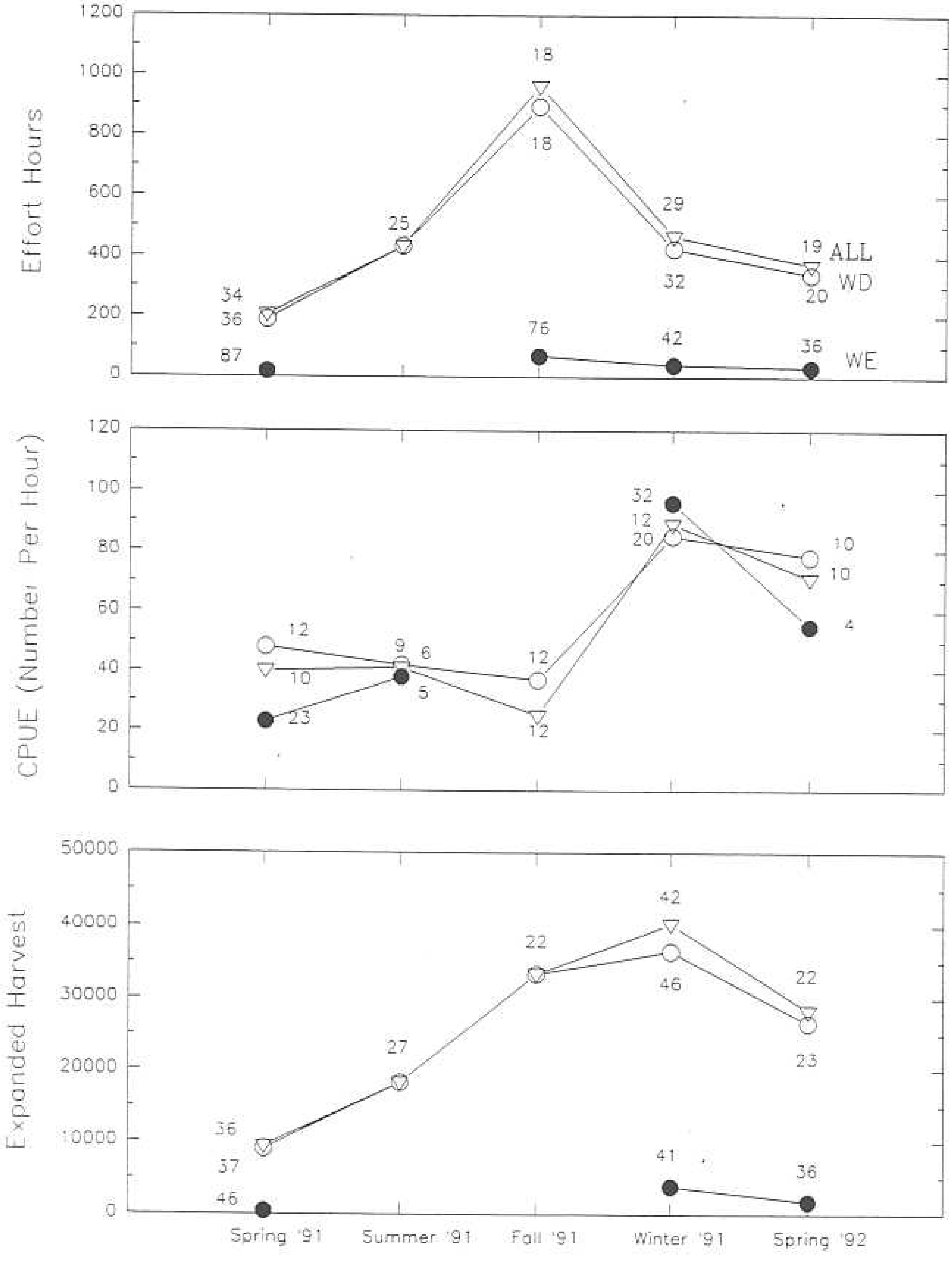



FIGURE 6: Quarterly Expanded Effort, CPUE and Expanded Harvest
AQUARIUM COLLECTORS

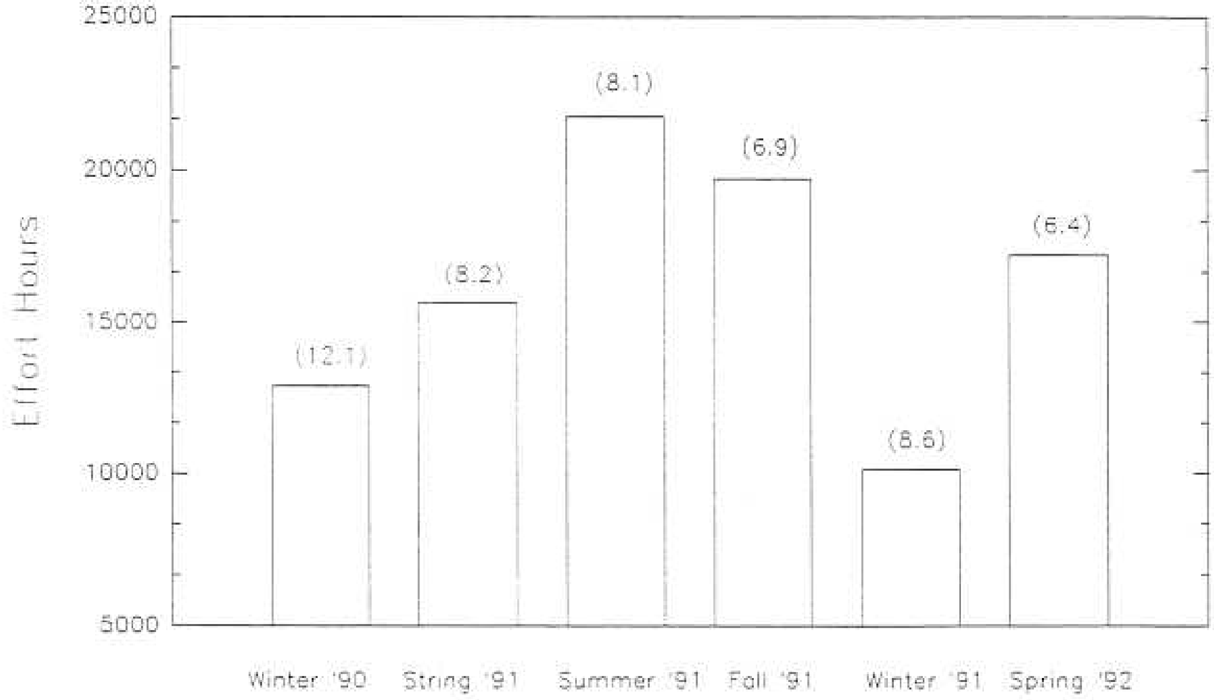



FIGURE 7: Estimated Quarterly Effort by All Active Methods Observed in Kaneohe Bay

Numbers in parentheses indicate relative standard error (RSE = SE/estimate x 100)